Modeling the optimum distribution of active power between plants by using thermal function

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Abstract

This paper presents a new algorithm for optimal power flow (OPF) based on thermal function techniques. The algorithm considers two sub-problems seeking for minimum cost of generation and minimum system transmission loss. These have been solved sequentially to achieve optimum allocation of real and reactive power generations with due consideration to system operating constraints pertaining to generation, bus-voltage and line flow limits. New models for handling system constraints have been developed to suit the thermal function based OPF algorithm. The mathematical models and algorithms are so developed to be solved by means of computer simulation of optimal power system models by thermal function. The potential of the new algorithm of OPF has been demonstrated through system data for electrical network. Results reveal that the proposed new algorithm has potential for on-line OPF solution.
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1. Introduction

In an optimal power flow (OPF) problem, total fuel cost and total transmission loss or some other appropriate objective functions are minimized subject to the system constraints. A lot of research work has been carried out in the past in the OPF area using several optimization techniques such as classical, linear, quadratic and non-linear programming methods. Lezjnyouk and Paotkina, in his review paper [1] concluded that thermal function method can be used to solve the problem of minimizing the active power losses in the electrical network, by simulating the network as active resistances (R-network) and find regulating devices will lead to optimum or economic distribution of currents in the networks [1]. In this paper, the thermal function is used to solve the multiple objective optimization problem associated with minimization of generation costs and minimization of transmission losses of a power system, as a one objective function.

The new algorithm for solving the OPF problem considered the twin sub-problems of minimizing total fuel cost and total system loss for optimum allocation of active and reactive power generations and transformer tap settings. The algorithm uses a new approach for linearizing various system constraints the two sub-problems have been solved sequentially till both cost of generations and system loss converge to a pre-specified tolerance.

The potential of the new algorithm for OPF has been demonstrated through data for power system consisting of three thermal stations and seven buses, and the results obtained by simulated model are shown in Section 6 with the relevant conclusions.

2. Thermal function

In technological systems a number of processes occur in such away that the response is minimized.

Maxwell definition that in a DC source, the current flow in the resistances in such away that the power will be minimized due to dissipation along the resistances [1].

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$$\Delta P = \frac{1}{2} \sum_{i=1}^{m} \sum_{j=1}^{m} [E_{ij} - (V_i - V_j)]^2 G_{ij} \qquad (1)$$

The function Eq. (1) will be minimum independent of the current flow in the resistances, E_{ij} is e.m.f of the branch, limited by the buses i and j; V_i, V_j the voltage of these buses; G_{ij} the active conductance of this branch; m is the number of buses in the network.

Eq. (2) is called the thermal function [1], and if we take the first derivation of Eq. (2), the result obtained will coincides with the first kerchief's law as the follows:

$$\partial \Delta P / \partial V_1 = 0; \quad \partial \Delta P / \partial V_2 = 0; \quad \ldots \partial \Delta P / \partial V_m = 0 \qquad (2)$$

Then,

$$\left. \begin{array}{l} V_1 G_{11} + V_2 G_{12} + \cdots + V_m G_{1,m} = J_1; \\ V_1 G_{12} + V_2 G_{22} + \cdots + V_m G_{2,m} = J_2; \\ \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \\ V_1 G_{m1} + V_2 G_{m2} + \cdots + V_m G_{m,m} = J_m. \end{array} \right\} \qquad (3)$$

where J current vectors in the buses; G_{ii} self-admittances; G_{ij} mutual-admittances. If we take the second derivation of Eq. (2), the result will be:

$$^2 \partial \Delta P / \partial V_1^2 = 2G_{11} > 0; \quad ^2 \partial \Delta P / \partial V_2^2 = 2G_{22};$$

$$^2 \partial \Delta P / \partial V_m^2 = 2G_{m,m} > 0. \qquad (4)$$

i.e. the second order derivation is usually positive, and actually, the distribution of currents between resistances in the circuits minimizes the active power losses.

3. Using thermal function in the electrical network

The minimum of Eq. (1) and the conditions of it obtained are defined in the result of the solution of linear system Eq. (3).

The thermal function Eq. (1) can be used to solve the problem of minimizing the active power losses in the electrical networks, which can be done by simulating the network is active resistances (R-network). On the other hand it is necessary to determine the conditions under which the current distribution established by means of R-network will exist in a real network with complex impedances, thus the problem of optimization electrical networks can be divided into two principle stages:

On the first stage—by means of R-network, the current distribution is determined and is called the economical currents, because it provides the minimum of active power losses.

On the second stage—by dividing the parameters of regulating devices such as the optimum ratio of transformers, optimum value of capacitances will lead to optimum or economic distribution of currents in the networks [2].

The simplest way of using the thermal function to modeling the optimum current distribution can be done

when the objective function is minimum losses, the considered approach can be used to modeling the process of optimum distribution of active power between plants and to modeling the process of complex optimization, i.e. to solve the problem associated with minimization of generation costs.

4. Optimization problem

The mathematical formulation of the optimization problem of daily operation planning consists of the objective function and the constraints. The objective function minimizes the total operation costs over the whole day [2–4]:

$$F = \sum_{j=1}^{N} (f_j) = \sum_{j=1}^{N} (A_{0j} + A_{1j} P_j + A_{2j} P_j^2) \Rightarrow \min \ \$/h \qquad (5)$$

Subject to:

$$\begin{array}{ll} P_j \min \leqslant P_j \leqslant P_j \max; & V_i \min \leqslant V_i \leqslant V_i \max \\ Q_j \min \leqslant Q_j \leqslant Q_j \max; & K_t \min \leqslant K_t \leqslant K_t \max \\ \sum_{J=1}^{N} P_j = P_{(load)} + \Delta P; & \sum_{J=1}^{N} Q_j = Q_{(load)} + \Delta Q \end{array} \qquad (6)$$

where, F is the cost function giving the total cost of all the fuel for the entire system and is the sum of the fuel costs of the individual units $f_1, f_2, \ldots, f_N$; A_0, A_1, A_2-are cost coefficients associated with real power generation at bus j; P_j, Q_j-active and reactive power generation at bus j; $P_{(load)}$, $Q_{(load)}$ active and reactive power loads respectively; N number of generation buses; n total number of buses; V_i max, V_i min–maximum and minimum limits of bus-voltage magnitudes at bus i; ∂_i max, ∂_i min–maximum and minimum limits of bus angle; K_t max, K_t min–maximum and minimum limits of turns ratio transformer; ΔP–transmission losses.

The new cost function F is formed by combining the total fuel cost and the equality constraint of Eq. (6) in the following manner:

$$H = (f_1 + f_2 + \cdots + f_N) + \lambda \left(P_{(load)} + \Delta P - \sum_{j=1}^{N} P_j \right) \qquad (7)$$

The augmented cost function H is often called the Lagrangian, and the parameter λ is called lagrange multiplier.

For minimum cost we require the derivative of H with respect to each P_j to equal zero, and so.

$$\frac{\partial H}{\partial P_j} = \frac{\partial}{\partial P_j}$$

$$\times \left[(f_1 + f_2 + \cdots + f_N) + \lambda \left(P_{load} + \Delta P - \sum_{j=1}^{N} P_j \right) \right]$$

$$= 0 \qquad (8)$$